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ABSTRACT

Students should use words (their own words) to learn physics,and that is why it is important for students learning introductory physics to write as they learn. To teach physics badly, teach it as a bunch of equations with no underlying meaning, or make it scary and nearly incomprehensible. Physics is really about subtle ideas and concepts--it is difficult because the ideas are new to most students. Writing helps students in introductory physics courses to deepen conceptual understanding; allows them to think in multiple ways; and entices them to enlarge upon an idea and connect it to other realms. Teachers should show students the relationship in symbols after the concept is firmly lodged in the mind; otherwise, students become focused on memorizing relatively sophisticated but intellectually limited procedural skills. (A figure describing the concepts of motion, force, and energy and consisting of nothing but mathematical equations illustrates introductory physics when it is taught badly; and a figure expressing the same concepts entirely in words illustrates introductory physics when it is taught well. (RS)

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From Mere Formulas to the Bigger Picture: Helping Students in Introductory Physics See Interconnectedness

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- Let me scare you to start off:

  The page titled "Introductory Physics When It's Taught Badly" shows everything that's wrong with the way introductory physics is taught:
  - it's just a bunch of equations
  - there's no coherence
  - there're no ideas underlying the equations/no meaning
  - it's scary, nearly incomprehensible (like magic)
  - it's the way most students see introductory physics because it's the way most introductory physics is taught
  - It's not what introductory physics is about!

- Now let me calm your fears:

  The page titled "Introductory Physics When It's Taught Well" is what introductory physics is really about
  - it's all ideas/concepts
  - it's difficult stuff because the ideas and concepts are new to most students; they don't have them before they walk into the class
  - also, the ideas/concepts can be subtle, and subtlety can be difficult

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- Here's what I think we should take away from this realization:

  To teach students introductory physics means to help them grasp new concepts. Concepts, of course, mean words. People (students included!) think in words, so it doesn't work to expect students to think, instead, in mathematical equations (the equation is a shorthand notation for the idea in words). Students should use words (their own words) to learn physics, and that's why it's important for students learning introductory physics (Physics 151) to write as they learn
  - to learn as they write
  - writing to deepen conceptual understanding
  - asking students to think in multiple ways about physics helps to deepen their understanding of how the world works
  - it entices students to enlarge upon the idea, and to connect it with other ideas from other realms (equations rarely, if ever, do this)
  - after the concept is firmly lodged in the mind, then show students the relationships in symbols (the elegance of a mathematical formula)
  - otherwise, students becomes focused on memorizing relatively sophisticated, but intellectually limited procedural skills
  - otherwise, they never learn what introductory physics is really about

Introductory Physics When It's Taught Badly

Motion: $\bar{v} = \frac{d}{t}$ $\bar{v} = \frac{x - x_o}{t}$ $v = v_o + at$

$\bar{v} = \frac{v_o + v}{2}$ $x = x_o + v_o t + \frac{1}{2} at^2$ $x = \frac{1}{2} at^2$

$v^2 = v_o^2 + 2a(x - x_o)$ $v_y = v_{yo} - gt$ $y = v_{yo} - \frac{1}{2} gt^2$

$v_y^2 = v_{yo}^2 - 2gy$ $y = \frac{1}{2} gt^2$ $R = \frac{v_o^2 \sin 2\theta_o}{g}$

Forces: $F = ma$ $F_g = w = mg$ $F_{fr} = \mu_k F_N$

$F_{fr} \leq \mu_s F_N$ $F_G = \frac{Gm_1m_2}{r^2}$ $F_c = m\frac{v^2}{r}$

$a_c = \frac{v^2}{r}$ $w = mg + ma$

Energy: $W = Fd\cos\theta$ $W' = \Delta KE + \Delta PE$

$W = \Delta KE$ $KE + PE = \text{constant}$ $KE = \frac{1}{2} mv^2$

$GPE = mgy$ $Heat = F_{friction}d$

$$\frac{1}{2} mv_1^2 + mgy_1 = \frac{1}{2} mv_2^2 + mgy_2$$

Introductory Physics When It's Taught Well

Motion: Predicting the future/Understanding the past

☞ If you know how things are, and know how they're changing, you can predict the future.

☞ Knowing how things are, and knowing how they've changed, you can understand the past.

Forces: Not the cause of motion, but
The cause of the change in motion.

Not what one thing does to another (Western, patriarchal, imperialist view), but
A mutual interaction between two things.

- ⇨ Zeroth Truth: Understanding means seeing the big picture
- ⇨ First Truth: No force ——> No change in motion
- ⇨ Second Truth: Yes force ——> Yes change in motion
- ⇨ Third Truth: The interaction is mutual (equal)

Energy: Something **shared, spent, never lost**

Everything that happens is part of **the Cosmic Dance**

☞ It's got a thousand faces: we need to recognize them all

☞ It's so freely shared: we need to keep track of every bit